PRINCIPLES OF TROPICAL LIVESTOCK PRODUCTION

MODULE 2.1
GENERAL MAKEUP AND FUNCTIONING OF THE RUMINANT ANIMAL

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2.1 GENERAL MAKEUP AND FUNCTIONING OF THE RUMINANT ANIMAL

Introduction

Welcome to our discussion on the Ruminant Animal! This Module contains 4 units:

⇒ Anatomy and Physiology of Ruminant Nutrition [What happens when ruminants eat?]

⇒ Anatomy and Physiology of Mammalian Reproduction as Applied to Ruminants [How do they produce young?]

⇒ Physiology of Lactation [How do female ruminants produce milk?]

⇒ Environmental Physiology [How do ruminants interact with their environment?]

Learning Objectives

The goal of this module is to provide you with a general understanding of the basic processes of ruminant production (their nutritional needs, their digestive operation, the ruminant reproductive process) and the interdependence of these with environmental factors.

> **The Importance of this Module:** This module is the foundation upon which all your knowledge of ruminants will be built. There are five (5) factors affecting or governing the production and management of all animals. These factors are Feeding and Nutrition; Breeding and Genetics or Reproduction; Housing and Environment; Health and Disease Prevention; and the Economic and Marketing Factors. The first four (4) are Biological and Environmental Factors, and will be dealt with in the main body of the Course. The fifth factor, the Economic Factor, will not be covered in this series of modules on intensive ruminant production. Module 2 attempts to bring into focus the basics of the Nutrition, Breeding and Environmental Factors. The Health factor will be covered within each of the production modules. Study this module well as it will form the basis for you having a better understanding of the individual animal species' production modules. The other modules to follow this one on ruminants will be Module 3: Sheep; Module 4: Goats; Module 5: Dairy; Module 6: Beef; Module 7: Buffaloes; and Module 8: Forages.

At the end of this module, you should:

➲ understand the principles of how ruminants convert feed to energy

➲ be familiar with the reproductive system of ruminant animals

- have a working understanding of the physiology of milk production and let down and
- have a working knowledge of how ruminants are affected by tropical conditions and other environmental factors.

MODULE 2.1 — UNIT 1

.1. Anatomy and Physiology of Ruminant Nutrition [Digestion in the Ruminant]

Introduction

Before we begin, we should attempt to address the following question: ***What are Ruminant animals?*** Ruminants are a division of a group of animals with even-toed hoofs (ungulates). They have a stomach with four complete cavities; the food of the first and second (the Reticulo-Rumen) being returned to the mouth, rechewed and swallowed, and digested in the other cavities. In addition, in the first two (2) (the Reticulum, and the Rumen) digestion of fibre is aided by microbes, which produce enzymes, which aid in fibre breakdown. These enzymes also breakdown protein. This unit describes the functions of the ruminant digestive organs and important considerations for ruminant feeding.

Quick Start h

The learning objective of this unit is: for you to have a working knowledge of ruminant digestive physiology for an application relative to your comprehension of the individual ruminant learning modules which would follow. Those of you who will be using this manual for learning in the "face-to-face" mode of an Undergraduate Programme, should use this module as revision of the relevant aspects of your Level 1 Animal Physiology, Level 2 Animal Physiology and Animal Nutrition. It is therefore important that all students, whether "face-to- face", or "Distance" Modes, use this module as the foundation upon which you will proceed to study Ruminant Animal Production.

The Lesson /

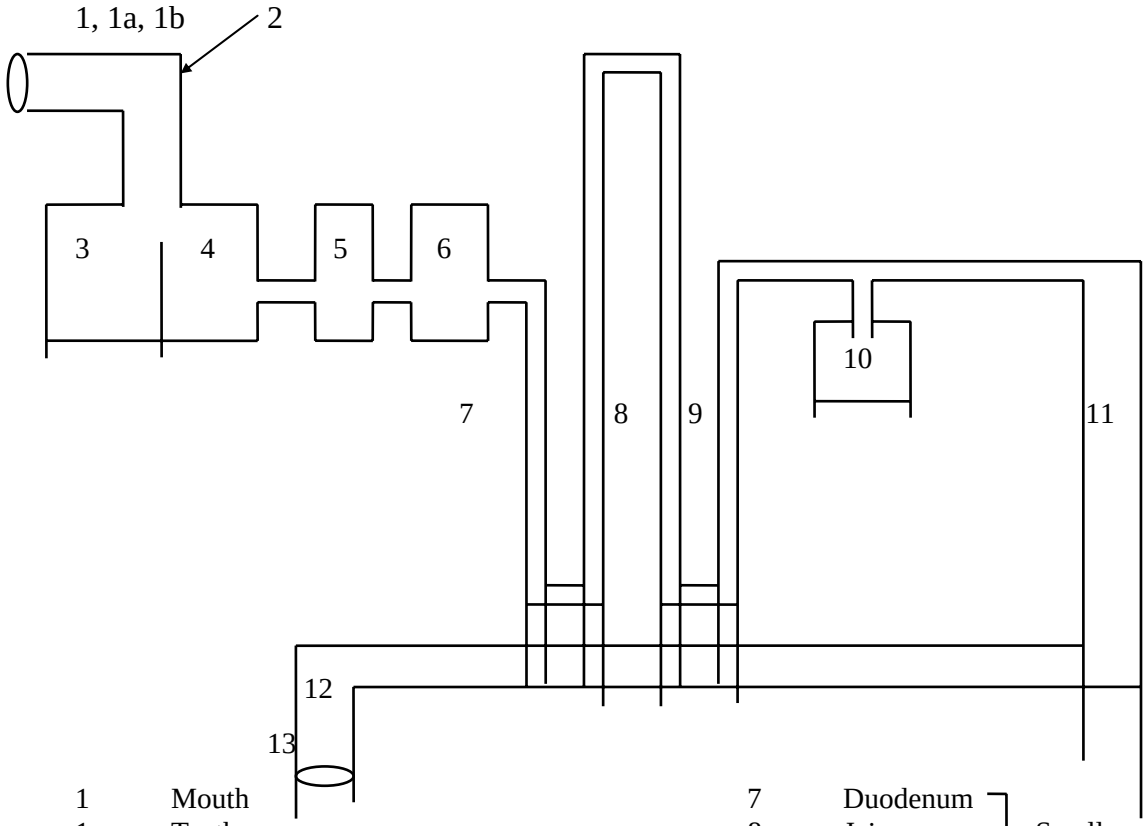
.1.1. The Ruminant Stomach

The true (glandular) stomach (or Abomasum) in the ruminant is preceded by three divisions (lined with stratified squamous epithelium), collectively known as the *fore-stomach* and this is divided into:

- The Reticulum
- The Rumen
- The Omasum.

These three fore-stomachs make up about 50% of the total digestive system of the ruminant. Food is soaked in the fore-stomach and subjected to digestion by microorganisms before being exposed to gastric digestion in the rest of the digestive tract.

Figure 2-1 presents a flow/block diagram of the typical ruminant digestive system.



1	Mouth		7	Duodenum	Small Intestine
1a	Teeth		8	Jejunum	
1b	Salivary Glands		9	Ileum	
2	Oesophagus		10	Caecum	Large Intestine
3	Reticulum	Ruminant Stomach	11	Colon	
4	Rumen		12	Rectum	
5	Omasum		13	Anus	
6	Abomasum				

Figure 2.1-1. Flow Diagram of the typical Ruminant Digestive System

.1.1.1. Reticulum

The **reticulum** is that part of the fore-stomach located closest to the head of the animal. The reticulum is also called the "honeycomb," because it is lined with mucous membranes, containing many intersecting ridges that subdivide its surface into "honey-comb-like" compartments. The surface is stratified squamous epithelium. (This is scientific talk for layers of thin, pliable, scaly, compactly joined tissue.) The reticulum is located immediately behind the diaphragm, which places it almost beside the heart.

NOTE: Any foreign objects such as wire or nails that may be swallowed tend to lodge in the reticulum and are in a very

good position to penetrate the heart. This is a common feature of what is called "Hardware Disease". The importance of this information is that you must always keep your pens and feed troughs free of small metallic and other debris, which could be easily taken up and swallowed by ruminants..

.1.1.2. The Rumen

The **rumen** is a large muscular sac that extends from the diaphragm to the pelvis and almost entirely fills the left side of the abdominal cavity. The rumen is subdivided into sacs by muscular pillars, which appear from the exterior of the rumen as grooves. Usually, the rumen is constantly contracting and moving. Healthy cows will have one to two rumen contractions per minute. The contractions:

- mix the rumen contents
- bring microbes into contact with new feedstuffs
- reduce flotation of solids, and
- move materials out of the rumen.

NOTE: A decrease in frequency of rumen movements, or a lack thereof, is one way of diagnosing sick animals. If all animals but one are ruminating or "chewing their cud", this suggests that that one animal may be unwell and should require some close-up observation.

Digestion of Energy Feeds in the Rumen

All **carbohydrates**, which include structural carbohydrates (such as, cellulose and hemicellulose of fibrous materials), fibre, starch of grains, sugars in plant cells and byproducts (soluble carbohydrates), are digested by rumen microbes. The microbial population digests approximately 30-50% of the cellulose and hemicellulose in the rumen. Starch is degraded 50-65% or more depending on the amount fed and how fast ingested materials move through the rumen. Most sugars (both sugars and molasses) are digested completely within the rumen.

In the rumen digested carbohydrates are converted into **volatile fatty acids** (VFAs) which serve as the primary energy source in ruminants. The volatile fatty acids are absorbed from the rumen into the blood stream and transported to the udder and other tissues where VFAs are used as sources of energy for:

- Maintenance
- Growth and Development
- Reproduction
- Work, and/or
- Milk Production.

The volatile fatty acids consist mainly of:

- Acetic acid,
- Propionic acid, and
- Butyric acid.

When large amounts of forage is fed, the formation of VFAs is as follows:

- Acetic acid predominates (60-70% of total) with
- Propionic acid in lesser amounts (15-20%) and
- Butyric acid (5-15%).

However, when grain feeding is increased or when finely ground forages are fed, the proportion changes:

- Acetic acid may decrease to 40% while
- Propionic acid may increase to 40% percent

Such a change in VFA production generally is associated with a reduction in milk fat test, which usually occurs when very little forage is fed with high levels of concentrate supplementation. The cow derives 50-70% of its energy from the VFAs produced in the rumen.

Now let's take a look at the way protein is broken down!!!

Protein (CP) and Nonprotein Nitrogen (NPN) Utilisation

Some of the **protein** (expressed as crude protein – CP) consumed by the cow escapes breakdown in the rumen. The extent of breakdown depends on protein solubility and resistance to breakdown. Protein that is undergoing fermentation in the rumen is converted to:

- Ammonia and
- Microbial protein.

NOTE:

1. *Ammonia* - Many rumen micro-organisms require ammonia (breakdown product of protein digestion in the rumen) for growth and synthesis of microbial protein. Ammonia may also be provided from nonprotein nitrogen (NPN) sources such as urea, ammonium salts, nitrates, and other compounds.
2. *Microbial Protein* - Rumen microbes convert the ammonia and organic acids into amino acids that are assembled into microbial protein. Excess ammonia may be absorbed from the rumen into the blood stream and voided in the urine via the kidneys.

3. *By-Pass Proteins* - Feed protein (that escapes breakdown in the rumen) and microbial protein pass to the abomasum and small intestine for digestion and absorption as amino acids.

4. *Protein* – Feed Protein is expressed as Crude Protein (CP), which is the nitrogen content of the feed (expressed as % N) multiplied by a factor of 6.25.

$$\therefore \% CP = \% N \times 6.25$$

[% N as determined by the Kjeldhal Method of Analysis]

Vitamin Synthesis

Vitamin synthesis in the rumen is sufficient for growth and maintenance. The rumen micro-organisms manufacture all of the B vitamins and vitamin K. Under most conditions, cattle with functioning rumens do not require supplemental B and K vitamins in their diet.

.1.1.3. Omasum

The **omasum** is a spherical organ filled with muscular laminae (thin sheets) that descend from the dorsum or roof. The mucous membrane covering the laminae is studded with short, blunt papillae (nipple-like projections) that grind roughage before it enters the abomasum (or true stomach). The omasum is located to the right of the rumen and reticulum just caudal (to the rear) behind the liver. The omasum of the sheep and goat normally is not in contact with the abdominal wall and is relatively much smaller than that of the cow.

.1.1.4. The Abomasum

The **abomasum** (true stomach) is the first glandular portion of the ruminant's digestive system. It is located ventral to the omasum and extends caudally (remember, towards the rear!) on the right side of the rumen.

The *pylorus* (terminal part of the abomasum) is a sphincter (thickening of circular smooth muscle fibres) at the junction of the stomach and small intestine.

The epithelium (a thin membranous tissue) of the abomasum changes abruptly from the stratified squamous (scaly) epithelium of the omasum, to a tall simple columnar epithelium capable of producing mucus. Presumably the mucus covering the stomach epithelium prevents the digestive juices from digesting the stomach cells.

Whew! Did you get all that? Take a look at the model of the digestive tract again.

.1.2. The Small Intestine

Based in part on histologic or microscopic structural differences, the small intestine is divided into three parts:

- Duodenum
- Jejunum
- Ileum

The **duodenum** is the first part of the small intestine. It is closely attached to the body wall by a short mesentery,[1] the mesoduodenum (middle duodenum). The duodenum leaves the pylorus[2] of the stomach and passes caudally (towards the back) on the right side toward the pelvic inlet (entrance). The duodenum then crosses to the left side behind the root of the great mesentery and turns forward to join the jejunum. The common bile duct from the liver and the pancreatic duct from the pancreas enter the duodenum a short distance behind the pylorus.

The **jejunum** is indistinctly separated from the duodenum. It begins approximately where the mesentery starts to become rather long.

The **ileum** is the last part of the small intestine. The jejunum and ileum are continuous, and there is no gross demarcation (boundary) between them.

.1.3. The Large Intestine

The large intestine consists of 2 parts:

1. The **cecum**, which is a blind sac, and
2. The **colon**, which consists of ascending, transversing, and descending parts.

The descending colon terminates as the **rectum** and **anus**.

[1] A fold of the peritoneum (a membrane that lines the abdominal cavity) that completely covers an intestine and connects it with the abdominal wall; especially, the fold covering the small intestine.

[2] The opening ("gatekeeper") between the stomach and the duodendum, surrounded by circular muscle fibers; also, the adjoining portion of the stomach.

.1.4. Functions of the Digestive Tract

Large quantities of gas, mostly carbon dioxide and methane, are produced in the rumen, which amount to *30-35 quarts (33.6 to9.2 litres) per hour of gas* (Yikes!) and must be removed or bloating occurs. Under normal conditions, distension from gas formation causes the cow to belch and eliminate the gas.

NOTE:	Bloat is a widespread digestive disorder, and the most common way of correcting it is with the use of a **Trochar** and **Cannular** . Contact your local vet by phone and inquire about the frequency of this in your area, and how to use the Trochar and Cannular in an emergency.

.1.5. Rumination

A cow may spend as much as 35-40% of each day ruminating (cud chewing).

NOTE:	That is why some students who chew gum in class are sometimes called RUMINANTS !!!!

The actual amount of **time spent ruminating** varies:

- When grain or finely -ground rations are fed— very little time.
- When roughage is fed — several hours.

Mature cattle spend little or no time chewing when eating. During rest periods, feed boluses (cuds) are regurgitated for rechewing to reduce particle size and for resalivation. Feed is more readily digested by rumen microbes as particle size is reduced. ***Ready to become a strict vegetarian?***

.1.6. Saliva Production

As much as 50 - 80 quarts (56.0 to 89.6 liters) of saliva can be produced by the salivary glands and added to the rumen each day. (**Wow! Have you figured out that ruminants probably need to be provided plenty of water? About at least this amount each day.)**

Saliva provides:

1. Liquid for the microbial population,
2. Liquid for the recirculation of nitrogen and minerals, and
3. Buffers the rumen.

NOTE:	Buffers help maintain the rumen at a constant PH of 6 - 6.5 to aid microbial population growth and avoid off-feed problems.

.1.7. Fat Digestion

Limited digestion of fat occurs in the rumen. Most of fat digestion occurs in the small intestine. Rumen micro-organisms change unsaturated[3] fatty acids into more saturated fats

[3] Not combined to the greatest possible extent; capable of uniting with certain other elements or compounds to form additional compounds.

through the addition of Hydrogen Molecules. Thus, less unsaturated fat is absorbed by cows than by simple-stomached animals.

.1.8. Calf Digestive System

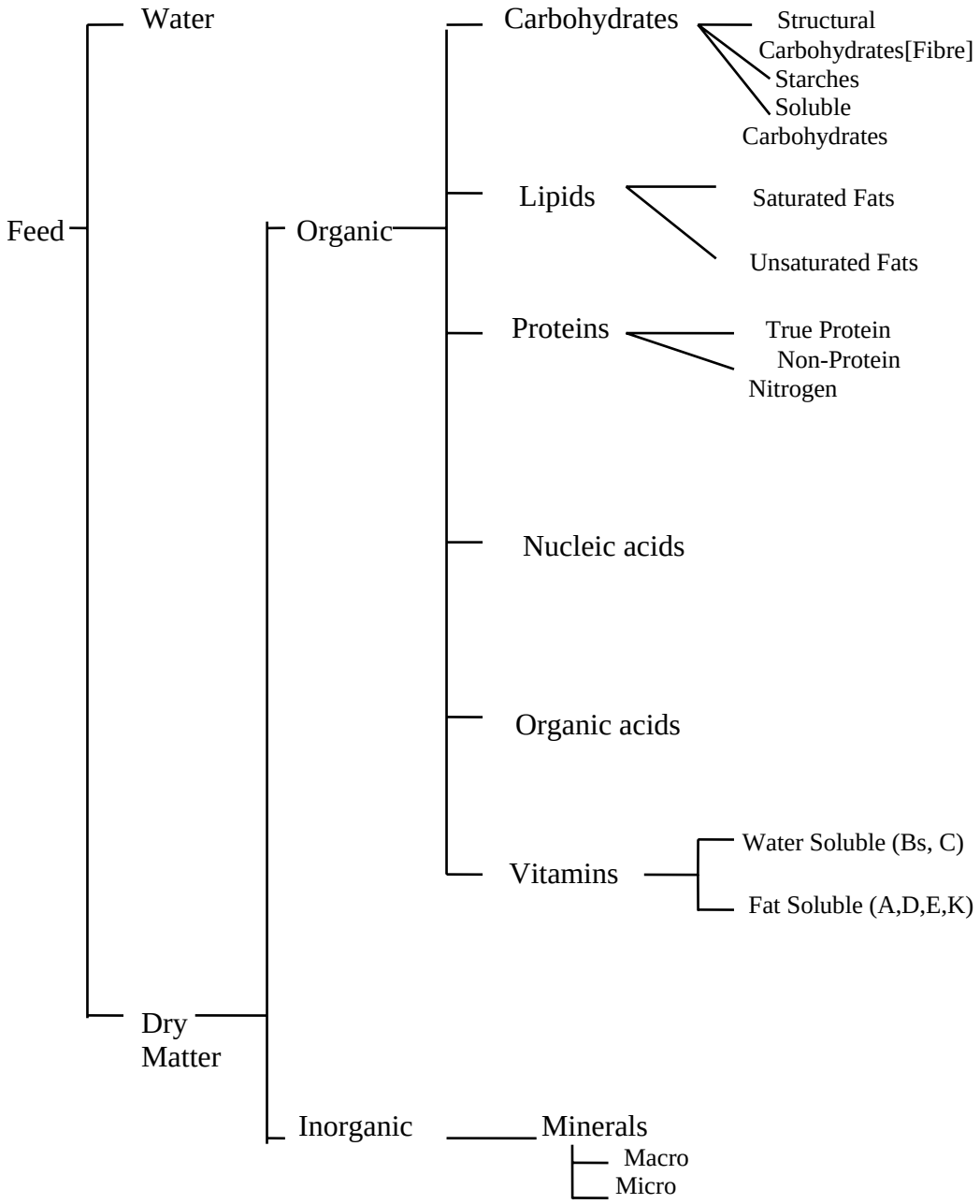
At birth and during the first three (3) weeks of life, the rumen, reticulum and omasum are underdeveloped in the calf. In contrast to the mature cow, the abomasum is the largest compartment of the stomach. At this stage of life, the rumen is nonfunctional and the calf is unable to digest some feeds which the more mature animal can. This is the reason why the feeding and management of early weaned calves (weaning at 5 to 8 weeks) requires special nutritional care and attention. This would be fully described to you in **Module 5: Unit 4**.

.1.9. Feed Nutrients

The food of farm animals typically consists of plants and plant products, although some foods of animal origin such as fish meal and milk are fed in limited amounts. The animals depend upon plants for their existence and consequently a study of animal nutrition must necessarily consider plant composition.

The main components of foods, plants and animals are described in Figure 2-2.

Figure 2-2. Components of Foods, Plants and Animals



.1.9.1. Water

The water content of the animal body varies with age:

- the **newborn animal** contains from 750 to 800 g water per kg body weight but this decreases with age;
- the **mature fat animal** to about 500 g water per kg body weight.

It is vital to the life of the organism that the water level in the body be maintained.

NOTE:	An animal will die more rapidly if deprived of water than if deprived of food. That is why water supply management is one of the most important components of any production system.

Water functions in the body as:

- a solvent in which nutrients are transported through the body
- a solvent in which waste products are excreted from the body and
- the regulator of animal body temperature.

Many of the chemical reactions brought about by enzymes take place in solution and involve *hydrolysis* (any decomposition involving the addition of water). Because of the high specific heat of water, large changes in heat production can take place within the animal with very little alteration in body temperature.

Water also has a high latent heat of evaporation, and its evaporation from the lungs and skin regulates animal body temperature. ***See how important water is?***

The animal obtains its water from three (3) sources:

- drinking water,
- water present in its food and
- metabolic water (formed during metabolism by the oxidation of hydrogen-containing organic nutrients).

The water content of food is very variable and can range from 60 g per kg fresh material in concentrates to over 900 g per kg in some root crops. The water content of growing plants is related to their stage of growth — younger plants contain more water than older plants. There is no evidence that under normal conditions an excess of drinking water is harmful. Animals normally drink what they require.

.1.9.2. Dry Matter

The dry matter ("DM") of foods is conveniently divided into:

- Organic and
- Inorganic materials [see Figure 2-2].

In living organisms there is no such sharp distinction.

.1.9.2.1. Organic compounds

Many **organic compounds** contain mineral elements as structural components:

Carbohydrate

The main component of the DM of pasture grass is carbohydrate. This is true of all plants and many seeds — the oilseeds, such as groundnuts, being exceptional in containing large amounts of protein and lipid material in the form of fat or oil.

In contrast, the carbohydrate content of the animal body is very low. One main reason for the differences in carbohydrate content between plants and animals is that:

- The cell walls of plants consist of carbohydrate material, mainly cellulose
- The cell walls of animals are composed almost entirely of protein.

Furthermore, plants store energy largely as carbohydrates, such as starch and fructans (fruit sugars), whereas an animal's main energy store is as fat.

Fat

Fat is the most important lipid present in both plants and animals. The fat content of the animal body is variable and is related to age, the older animal containing a much greater proportion of fat than the younger animal. The lipid content of plants is relatively low, (*i.e.*, pasture grass contains 40 to 50 g per kg DM[4]). Many of the lipids and carbohydrates in plants and animals contain phosphorus.

Nitrogen Compounds

1. *Proteins* — In both plants and animals, proteins are the major nitrogen compounds. In plants, where most of the protein is present as enzymes, the concentration is high in the young growing plant and falls as the plant matures. In animals, muscle, skin, hair, feathers, wool and nails contain protein. Proteins are made up of amino acids.

NOTE: The expression of the quantity of the Crude Protein (CP) in a feed or compound is the %N x 6.25.

2. *Nucleic acids* — Like proteins, nucleic acids are also nitrogen compounds and they play a basic role in the synthesis of proteins in all living organisms. They also carry the genetic information of the living cell.

3. *Non-Protein Nitrogen (NPN)* - These are nitrogen containing compounds which, because of their Crude Protein (CP) equivalent (%N x 6.25) are included in the diets of ruminants. The microbial activity in the rumen breaks down the NPN into Ammonia.

[4] Dry Matter.

Organic Acids

Although organic acids are normally present in small quantities, they nevertheless play an important role as intermediates in the general metabolism of the cell.

The organic acids that occur in plants and animals include:

- Citric acids
- Malic acids
- Fumaric acids
- Succinic, and
- Pyruvic acid.

Other organic acids occur also called Volatile Fatty Acids (VFAs) as fermentation products in the rumen, or in silage, and these include:

- Acetic acid
- Propionic acid
- Butyric acid
- Lactic acid

Vitamins

Vitamins are present in plants and animals in minute amounts, and many of them are important as components of enzyme systems. Important differences between plants and animals are:

- Plants can synthesise all the vitamins they require for metabolism
- Animals cannot synthesise all the vitamins they require, or have very limited powers of vitamin synthesis, and are dependent upon an external supply.

Vitamins are described based on their solubility in either water or fat. They are therefore classified as follows:

Fat Soluable Vitamins

Vitamin	Chemical Name
A	Retinol
D_2	Ergocalciferol
D_3	Cholecalciferol
E	Tocopherol
K	Phylloquinone

Water Soluble Vitamins	
Vitamin	Chemical Name
B_1	Thiamine
B_2	Riboflavine
B_6	Pyridoxine
B_{12}	Cyanocobalamine
Unnumbered B Vitamins	Nicotinamide (niacin)
	Biotin
	Panthotenic Acid
	Folic Acid
	Choline
Vitamin C	Ascorbic Acid

.1.9.2.2. Inorganic matter

Inorganic matter contains all those elements present in plants and animals other than carbon, hydrogen, oxygen and nitrogen. The major components of the ash of animals are calcium and phosphorus. The main inorganic elements in plants are potassium and silicon. These inorganic substances are called Macro- and Micro-Minerals.